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Mikroyannidis, Alexander; Lefrere, Paul and Scott, Peter (2010). A semantic knowledge base for personal learning and cloud learning environments. In: Workshop on Supporting eLearning with Language Resources and Semantic Data (at LREC 2010), 22 May 2010, Valletta, Malta.

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# A Semantic Knowledge Base for Personal Learning and Cloud Learning Environments

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## Abstract

Personal Learning Environments (PLEs) and Cloud Learning Environments (CLEs) have recently encountered a rapid growth, as a response to the rising demand of learners for multi-sourced content and environments targeting their needs and preferences. This paper introduces a semantic knowledge base that utilises a multi-layered architecture consisting of learning ontologies customized for certain aspects of PLEs and CLEs. A number of stakeholder clusters, including learners, educators, and domain experts, are identified and are assigned distinct roles for the collaborative management of this knowledge base.

## 1. Introduction

Personal Learning Environments (PLEs) and Cloud Learning Environments (CLEs) are gradually gaining ground over traditional Learning Management Systems (LMS) by facilitating the lone or collaborative study of user-chosen blends of content and courses from heterogeneous sources, including Open Educational Resources (OER).

PLEs follow a learner-centric approach, allowing the use of lightweight services and tools that belong to and are controlled by individual learners. Rather than integrating different services into a centralised system, PLEs provide the learner with a variety of services and hands over control to her to select and use these services the way she deems fit (Chatti *et al.*, 2007).

CLEs extend PLEs by considering the cloud as a large autonomous system not owned by any educational organisation. In this system, the users of cloud-based services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services. This approach has the potential to enable and facilitate both formal and informal learning for the learner. It also promotes the openness, sharing and reusability of OER on the web (Malik, 2009).

In the context of the European project ROLE (Responsive Open Learning Environments - [www.role-project.eu](http://www.role-project.eu)) we are targeting the adaptivity and personalization of learning environments, in terms of content and navigation, as well as the entire learning environment and its functionalities. We propose the use of ontologies to model various aspects of the learning process within such an environment. In particular, we consider a semantic knowledge base as the core of the learning environment, enabling the collaboration between diverse stakeholder clusters.

The remainder of this paper is organised as follows. Section 2 describes the OpenLearn case study, consisting of a traditional LMS into transition towards the PLE and CLE paradigms. Section 3 introduces the architecture of the proposed semantic knowledge base and discusses the various learning ontologies that formulate it. Section 4

presents integration mechanisms for the different layers of the knowledge base. Section 5 describes the involved stakeholder clusters and their roles within the management of the knowledge base. Section 6 discusses certain challenges arising from the collaborative nature of the management of the knowledge base. Finally, the paper is concluded and the next steps for progressing this work are provided.

## 2. The OpenLearn case study

The Open University ([www.open.ac.uk](http://www.open.ac.uk)) provides a wide range of OER through the OpenLearn educational environment (<http://openlearn.open.ac.uk>). OER can be described as “teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or repurposing by others depends on which Creative Commons license is used” (Atkins *et al.*, 2007). OER are freely available on the web and can be accessed through common web sites or Virtual Learning Environments (VLEs), and more recently through PLEs and CLEs. They can be used, edited and shared by any interested party, such as learners, teachers, institutions, and learning communities.

OpenLearn users have the ability to learn at their own pace, keep a learning journal in order to monitor their progress, complete self assessment exercises, and discuss with other learners in forums. OpenLearn has gathered the interest of a wide audience ranging from governmental and non-governmental entities interested in promoting continuing professional development, public and private higher education institutes, academic teachers, training course designers, graduate and postgraduate students, educational researchers, and generally anyone interested in informal learning (Okada, 2007).

OpenLearn is essentially a traditional LMS, based on the Moodle platform (<http://moodle.org>), following a course-based paradigm, rather than a learner-based one. It has been built around units of study and not the personal profiles of learners. Currently, OU students are missing a place where they can aggregate the content offered by different OU services, such as OpenLearn and iTunesU, and mix it together with other educational



Figure 1. Climate change OER in OpenLearn (<http://tinyurl.com/yene49o>)

content. Therefore, what we aim to offer OU students in the context of ROLE, is a combined aggregator and e-portfolio, where they can set their learning goals, gather and organise various learning resources, monitor their progress, get recommendations from the system and their peers, and connect with other learners.

In order to explore the present limitations of OpenLearn, we have been comparing its capabilities with those of a PLE, by delivering the same learning resources with both approaches. For this purpose, we have created a collection of OER related to the UK 10:10 climate change campaign (<http://www.1010uk.org/>). Figure 1 shows this collection delivered by the existing OpenLearn environment, featuring OpenLearn courses and OU albums from iTunesU. In addition, content from external sources, such as YouTube and SlideShare, is included. However, syndication from dynamic Web 2.0 sources, such as the blogosphere, Twitter, and FriendFeed, is not supported.

On the other hand, the PLE of Figure 2 is a showcase of a widget-based environment hosting the same climate change resources as in OpenLearn, in addition to dynamic Web 2.0 sources. Compared to OpenLearn, this approach offers more flexibility in terms of creating new

widgets, configuring them, tagging them, and organising them into thematic categories in different tabs.

In the context of the ROLE project, we are working on the transition from the LMS-based approach of OpenLearn towards the PLE and CLE paradigms, by putting emphasis to the needs and preferences of learners. In particular, we aim at providing them with a wider range of OER to choose from, both from OpenLearn as well as from external Web 2.0 sources. However, discovering OER from such a wide range is not an easy task; therefore providing the learners with OER recommendations based on information from their profiles and portfolios is very important.

We propose the use of ontologies to model various aspects of the learning process within the transformed OpenLearn environment. In particular, we consider a semantic knowledge base as the core of this learning environment, enabling the use of metadata and ontologies to annotate learning resources, and model various aspects of the learning process, such as learner profiles. The curation of the proposed semantic knowledge base is supported by the active involvement and collaboration between different stakeholder clusters.

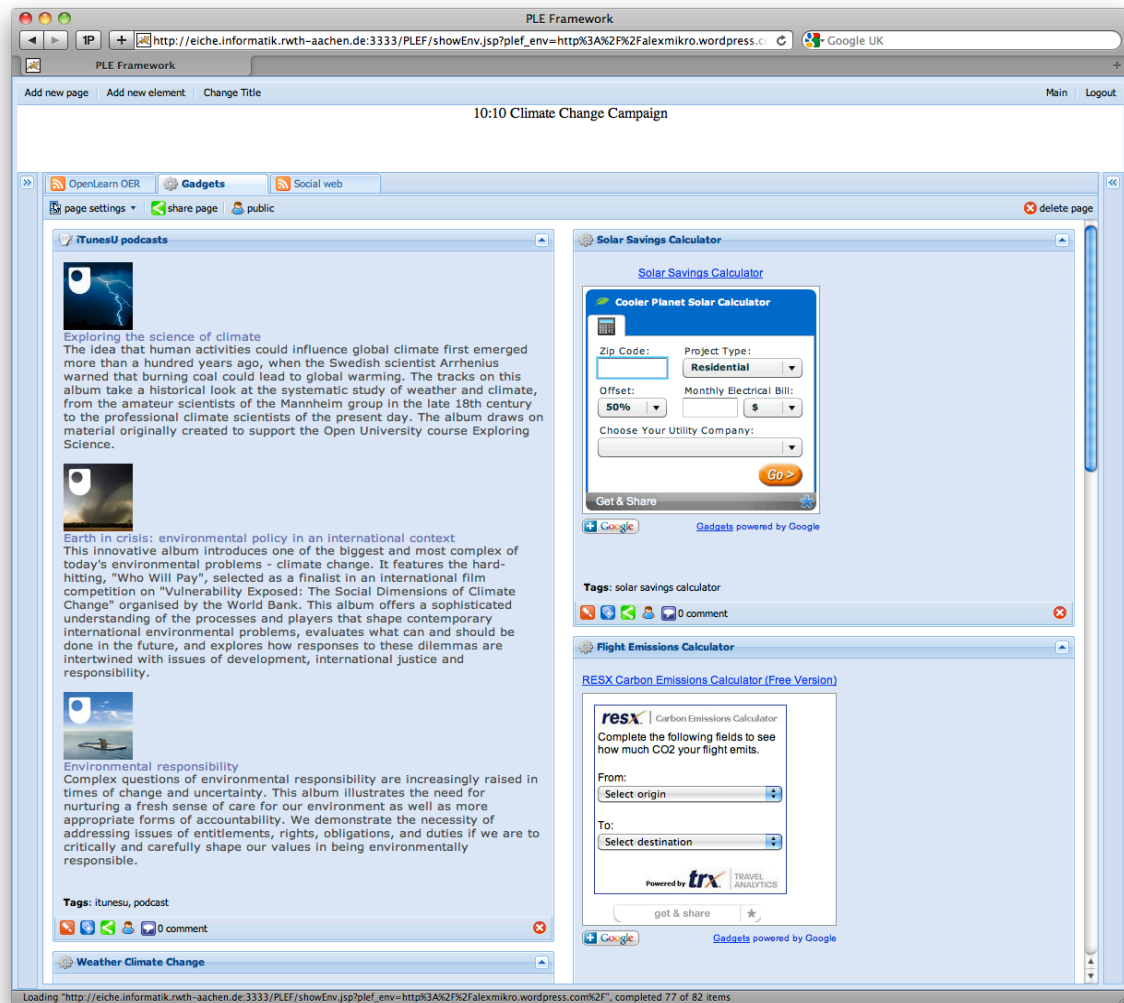


Figure 2. A widget-based PLE for climate change OER (<http://tinyurl.com/m6zrhl>)

### 3. Semantic knowledge base architecture

In order to efficiently manage the metadata associated with different aspects of the learning process, we propose their organisation into a number of ontology layers. Figure 3 shows the multi-layered semantic knowledge base adapted from the Heraclitus II framework (Mikroyannidis and Theodoulidis, 2006, Mikroyannidis, 2007, Mikroyannidis and Theodoulidis, 2010).

In this pyramid, the lower layers represent more generic and all-purpose ontologies, while the ontologies of the upper layers are customized for certain uses within a PLE or CLE. When traversing the pyramid from bottom to top, each layer reuses and extends the previous ones. In addition, whenever a layer extends the ones below it (e.g. with the insertion of new concepts), these extensions are propagated to the lower layers. Different stakeholder clusters curate each layer, depending on the expertise that each layer requires. The integration of the ontology pyramid layers is achieved with the use of ontology mappings between ontologies belonging to the same or different layers.

Starting from the top of the pyramid, the *Learner layer* contains ontologies that model the profiles of the learners involved in the learning process. In particular, the ontologies of this layer model the learners' profiles according to their interests, goals, preferences, and skills. Some ontology standards corresponding to this layer are the IEEE Learning Objects Metadata Standard (LOM) ([http://ltsc.ieee.org/wg12/files/LOM\\_1484\\_12\\_1\\_v1\\_Final\\_Draft.pdf](http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf)), the IEEE Personal and Private Information for Learner (IEEE PAPI) both developed by the IEEE Learning Technology Standards Committee (LTSC), the IMS Learner Information Package (LIP) (<http://www.imsglobal.org/profiles>), and the IMS Reusable Definition of Competency and Educational Objective (RDCEO) (<http://www.imsglobal.org/competencies>).

The *Learning Resource layer* models the learning resources that are employed within a PLE or CLE by learners. These resources are mainly widgets of educational tools and content. For example, the climate change PLE of Figure 2 includes widgets of:

- OpenLearn OER
- iTunesU albums
- External resources, e.g. blog feeds, YouTube videos,

- SlideShare presentations, Google gadgets, etc.
- Knowledge maps

The ontologies of the Learning Resource layer are constructed out of annotations of these widgets. These annotations can be user-generated tags, or automatically generated semantic annotations, e.g. with the use of IE (Information Extraction) and NLP (Natural Language Processing) techniques. Apart from the Learner layer, the IEEE Learning Objects Metadata Standard (LOM) also corresponds to this layer, as it defines models for learning objects, including multimedia content, instructional content, as well as instructional software and software tools.

The *Learning Domain layer* models the learning domain of interest. These are more generic ontologies describing a certain domain of interest to the learner, e.g. bioinformatics. The ontologies of the Gene Ontology (GO) project (The Gene Ontology Consortium, 2000) and the Foundational Model of Anatomy (FMA) (Cornelius Rosse, 2003) are some widely used domain ontologies in bioinformatics.

Finally, the *Lexical layer* contains domain-independent ontologies of a purely lexicographical nature. An example of such an ontology is the widely adopted WordNet (Fellbaum, 1998). A lexical ontology is the most generic form of ontology that can be constructed. The ontologies of this layer can be used to model practically any domain. The ontologies of all the other layers are independent of the language used, or other linguistic issues, which concern only this layer.

Although lexical ontologies constitute a strong basis for the construction of any domain-specific ontology, their relations tend quite often to be imprecise and thus not suitable for logical reasoning. This can be addressed with the use of more strictly constructed, general purpose ontologies, such as SUMO (Sevcenko, 2003). Such models can act as structuring mechanisms for lexical ontologies or intermediates between lexical and domain

ontologies.

#### 4. Knowledge base integration

The integration of the ontology pyramid layers into a single manageable scheme is achieved with the use of ontology mappings. In terms the layers of the ontology pyramid being mapped, ontology mappings are either *intra-layer*, mapping ontologies of the same ontology layer, or *inter-layer*, mapping ontologies belonging to different layers.

From an architectural point of view, ontology mappings can be either *structural*, namely referring to the structure of the mapped ontologies, e.g. via is-a relations, or *semantic* when mapping two ontology objects via a semantic relation, such as an employer-employee relation. OWL Full (Bechhofer *et al.*, 2004) offers a variety of constructs for representing structural ontology mappings, including `owl:subClassOf`, `owl:sameAs`, `owl:inverseOf`, `owl:equivalentClass`, and `owl:equivalentProperty`.

Ontology mappings are particularly useful for the extraction of recommendations to the learner, as they link her profile to learning resources, as well as to profiles of other learners. They can therefore be used to recommend learning resources of potential interest to the learner. They can also be used to recommend a 'study-buddy', with whom the learner shares common abilities and interests.

#### 5. Stakeholder clusters

Since each ontology layer represents a different degree of specialization, different stakeholder clusters are required to contribute to the curation of each layer. Starting from the bottom of the pyramid, lexicographers have the knowledge on language structures that is required in this level. Domain experts need to be employed for the next layer. These are professionals on a certain domain, e.g. biologists are responsible for a biology-related ontology.

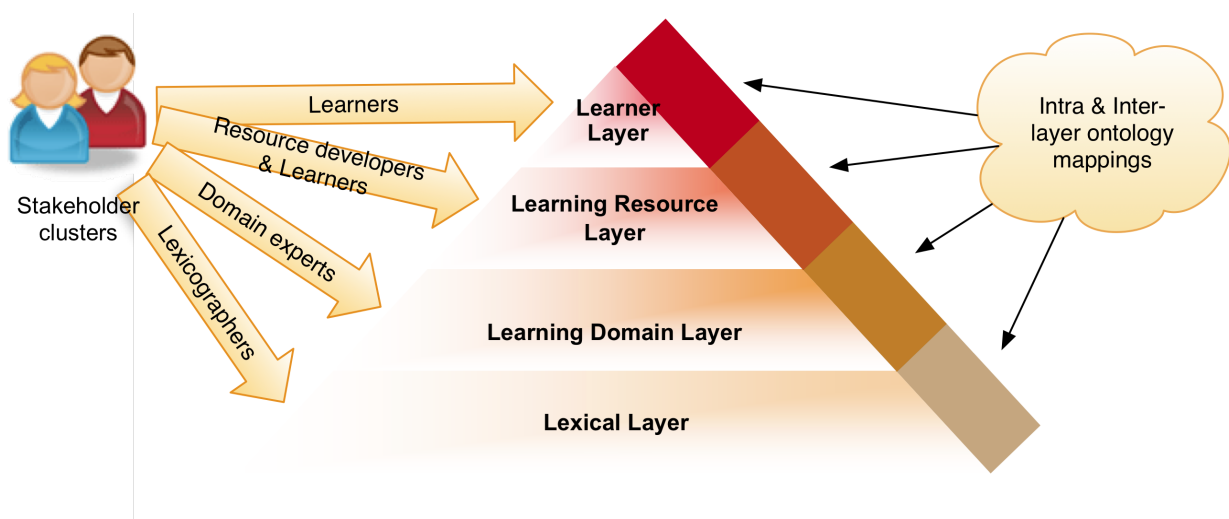


Figure 3. Multi-layered semantic knowledge base

For the Learning Resource layer, a more diverse group is suitable: producers and consumers of learning resources. The producers are those that develop learning resources, either content or tools. They can be lecturers, learning designers, or team leaders who develop new courses, workshops or training sessions and author new learning material. The consumers are learners who use and annotate the offered learning resources.

Finally, the Learner layer is curated by learners, who provide information about themselves in order to receive recommendations about learning resources and create personal networks with users from different learning environments, with whom they may share common learning interests.

Depending on the scope of intra and inter-layer ontology mappings, these are performed by one or more stakeholder clusters. For example, an inter-layer ontology mapping between the lexical and the domain layer will be created jointly by the stakeholder clusters of these two layers, namely lexicographers and domain experts. Intra-layer ontology mappings are performed by the stakeholder cluster of the corresponding layer. The assignment of stakeholder clusters as curators of the ontology pyramid layers is summarized in Table 1.

Ontology layer	Stakeholder cluster
Lexical layer	Lexicographers
Learning domain layer	Domain experts
Learning resource layer	Learning resource developers / Learners
Learner layer	Learners
Inter-layer ontology mappings	Stakeholder clusters of corresponding layers
Intra-layer ontology mappings	Stakeholder cluster of corresponding layer

Table 1. Assignment of stakeholder clusters as curators of the semantic knowledge base

## 6. Challenges in collaborative ontology management

Collaboration between stakeholder clusters in curating the semantic knowledge base is essential; however, it involves several challenges, including concurrency, consistency, and scalability issues. We will be targeting the following set of parameters for collaborative ontology management, as outlined in (Bao et al., 2006):

- **Knowledge integration:** A fundamental task in a collaborative environment is the integration of contributions from multiple participants. The proposed semantic knowledge base consists of a multi-layer architecture that is curated by diverse clusters of stakeholders. Reusability and integration is supported through ontology mappings.
- **Concurrency management:** Different ontology authors need to be able to work on different parts of the knowledge base simultaneously. In case the same part of the knowledge base is concurrently edited by more than one author, this can cause

conflicts. Various technologies can be used to address this issue, such as CVS (The Gene Ontology Consortium, 2000), Wiki (Auer et al., 2006, Schaffert, 2006), or peer-to-peer based solutions (Becker et al., 2005, Xexeo et al., 2004).

- **Consistency maintenance:** Parts of the knowledge base curated by different authors may be inconsistent with each other, since an ontology usually reflects the point of view of each author. Mechanisms for structural and semantic consistency preservation as well as change propagation need to be provided to ensure that the knowledge base is free of inconsistencies at all times.
- **Privilege management:** In order to ensure the accuracy of the knowledge base, a collaborative environment needs to assign different levels of privileges to its users, based on their expertise, authority, and responsibility. Our architecture is based on a flat scheme regarding privilege management, by giving each stakeholder cluster equal privileges in their layer of responsibility.
- **History maintenance:** Collaborative environments should provide the means to recover from wrong or unintended changes to the knowledge base. All changes to the knowledge base should be thus recorded in order to be able to track the authorship of a change and to prevent loss of important information. The bitemporal ontology model of Heraclitus II (Mikroyannidis, 2007) retains the necessary information to achieve this goal.
- **Scalability:** Long-term collaboration of diverse parties usually increases the size of knowledge bases; therefore, a collaborative environment has to be scalable to large ontologies. This is particularly important in the abundant environment of CLEs, where a wide variety of cloud-based services is employed.

## 7. Conclusion and next steps

PLEs and CLEs address the crucial demands of today's learner for a personalized and adaptive learning environment. In order to achieve these goals, we propose the use of ontologies for modeling the learning process and assigning distinct curator roles to the involved stakeholder clusters. We perceive a semantically enhanced PLE or CLE as the evolution of the present OpenLearn environment, as well as the evolution of LMS-based approaches in general.

We are currently in the process of refining the specifications of the proposed semantic knowledge base for addressing particular requirements of the OpenLearn case study. This refinement includes reviewing existing ontology standards in terms of their suitability to be reused, repurposed and adapted within an OpenLearn-specific ontology pyramid.



## 8. Acknowledgements

The research work described in this paper is partially funded through the ROLE Integrated Project, part of the Seventh Framework Programme for Research and Technological Development (FP7) of the European Union in Information and Communication Technologies.

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